Selected lower extremity alignment and range of motion measurements and their relationships to lateral knee pain

by Jaice Elizabeth Desi Flood

A thesis submitted in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE in Physical Education

Montana State University

Abstract:
This study was designed and conducted in an attempt to determine whether or not a relationship existed between lower extremity alignment and selected ranges pf motion of the hip, knee, ankle and subtalar joints and the incidence of lateral knee pain in runners.

Sixty runners served as subjects for this study. These subjects were divided into two classifications: 1) runners who had experienced lateral knee pain and 2) runners who had not experienced lateral knee pain.

Twenty-two lower extremity alignment and range of motion measurements were taken for each subject. An analysis of variance showed a significant difference between the runners who had experienced lateral knee pain and the runners who had not experienced lateral knee pain therefore a Duncan's Multiple Comparison was applied to the data.

The Duncan's Multiple Comparison showed two of the variables to be significantly related to lateral knee pain in runners. These two variables were a lack of flexibility in the hamstring muscle group and limited internal rotation of the lower leg.

It was recommended that runners experiencing lateral knee pain employ various stretching techniques to increase the flexibility of the hamstring muscle group. Also suggested was strengthening the internal rotators of the lower leg to increase the degree of internal rotation of the lower leg.

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MONTANA STATE UNIVERSITY
Bozeman, Montana

June, 1980

ACKNOWLEDGMENTS

The author would like to express her gratitude to Anne C. Brandenburg for her patient instruction in the use of the Phillip's Biometer and for her overall encouragement in the early stages of this study.

Thanks are also extended to her husband, Stephen Flood without whom there would have been no Inter-Ex I and to Dr. Al Suvak for his help and understanding in the statistical analysis of this study.

A very special thank-you is extended to Dr. Ellen Kreighbaum whose encouragement and professional guidance made this study a reality.

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ABSTRACT

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Sixty runners served as subjects for this study. These subjects were divided into two classifications: 1) runners who had experienced lateral knee pain and 2) runners who had not experienced lateral knee pain.

Twenty-two lower extremity alignment and range of motion measurements were taken for each subject. An analysis of variance showed a significant difference between the runners who had experienced lateral knee pain and the runners who had not experienced lateral knee pain therefore a Duncan's Multiple Comparison was applied to the data.

The Duncan's Multiple Comparison showed two of the variables to be significantly related to lateral knee pain in runners. These two variables were a lack of flexibility in the hamstring muscle group and limited internal rotation of the lower leg.

It was recommended that runners experiencing lateral knee pain employ various stretching techniques to increase the flexibility of the hamstring muscle group. Also suggested was strengthening the internal rotators of the lower leg to increase the degree of internal rotation of the lower leg.

Chapter 1

INTRODUCTION

The efficiency of foot contact, midstance phase, toe-off and swing phase has a great deal of influence on performance and the ability of the body to withstand stress according to Subotnick. (Subotnick, 1975) A runner's foot that strikes the ground biomechanically correctly is supinated and therefore the major portion of the weight lands on the lateral border of the calcaneus or heel. After contact the foot then immediately pronates allowing for the absorption of the shock of landing. Following pronation, the foot resupinates allowing the calcaneus to be perpendicular to the ground and the five metatarsal heads to be in contact with the running surface at the midstance phase of the running gait. The foot continues to supinate past its neutral position and becomes a rigid lever in order to provide propulsion at the toe-off phase, and still maintain a stable foot. (Aronson, 1977)

Proper running gait is important because extreme stress can lead to overuse syndromes such as lateral knee pain. Henderson (1974: 124) supported this theory when he wrote,

> The foot, podiatrists say, is the source of the great majority of athletic injuries--not only foot injuries, but those in the ankle and shin and knee and on up to the back. The foot meets the ground, and when it strikes improperly the entire leg works improperly. When that odd shock is taken up to a thousand times a mile, there's trouble at the most vulnerable points.

The most accepted method of reducing overuse syndromes is to alter foot plant by the use of orthotics. (Subotnick, 1975) Once the lower extremity is placed in an alignment in which the subtalar joint is in neutral position it can best function without overstress to the supporting structures.

> Knowing the source of the problem and what to do with it leaves podiatrists a long way from being able to deal most effectively with it. They've only recently opened the gate on a new way to handle athletes, and they've staked out the rough boundaries. Much exploring remains to be done inside the boundaries.
> (Henderson, 1974, 124)

There is a very real need for more research in this area, which is clearly indicated by Henderson (1974: 124) when he cites, "... podiatrists have determined that from 50 to 70 percent of athletes studied have foot abnormalities which could lead to trouble when put under enough stress." It is not too difficult to accept that athletes could be put under enough stress to create overuse problems when considering that a runner who puts in 100 miles per week plants each foot approximately 3,000,000 times a year.

Statement of the Problem

The general purpose of this study was to measure and statistically analyze lower extremity alignment and range of motion to determine if a relationship existed between any of the measurements taken and lateral knee pain. Lower extremity alignment and range of motion were described by the measures of forefoot valgus and varus, foot position

during weight bearing and selected ranges of motion at the hip, knee, ankle and subtalar joints.

Specifically this study attempted to determine whether the measures of forefoot valgus and varus, foot position during weight bearing, and selected ranges of motion at the hip, knee, ankle and subtalar joints as identified by the 22 measurements taken, were significantly different between persons who had experienced lateral knee pain and persons who had not experienced lateral knee pain. Further this study attempted to determine which, if any, of the measurements taken could be used to predict the incidence of lateral knee pain in runners.

Hypotheses

Null Hypothesis. It was hypothesized that there would be no significant difference in the lower extremity alignments, as described by the measures of forefoot valgus and varus, foot position during weight-bearing and selected ranges of motion at the hip, knee, ankle and subtalar joints between those persons who had experienced lateral knee pain and those persons who had not experienced lateral knee pain. Therefore separate populations could not be identified in terms of lower extremity alignment and range of motion. It was also hypothesized that none of the measures of forefoot valgus and varus, foot position during weight-bearing or selected ranges of motion at the hip, knee, ankle and subtalar joints would vary significantly between the two previously cited test groups. Further it was hypothesized that

none of the twenty-two measures taken could be used to predict the occurrence of lateral knee pain in runners.

Each of these hypotheses would be tested independently at the .05 level of significance.

Alternate Hypothesis. It was hypothesized that there would be a significant difference in the lower extremity alignments and ranges of motion, as described by the measures of forefoot valgus and varus, foot position during weight-bearing, and selected ranges of motion at the hip, knee, ankle and subtalar joints between those persons who had not experienced lateral knee pain and those persons who had experienced lateral knee pain. Therefore separate populations could be identified in terms of lower extremity alignment and range of motion. It was also hypothesized that some of the measures of forefoot valgus and varus, foot position during weight-bearing and selected ranges of motion at the hip, knee, ankle and subtalar joints would vary significantly between the two previously cited test groups. Further it was hypothesized that some of the 22 measurements taken could be used to predict the occurrence of lateral knee pain in runners. Each of these hypothesis would be tested independently at the .05 level of significance.

Definition of Terms

Lateral Knee Pain. Lateral knee pain was defined as an overuse syndrome, a condition that arises from repeated microtrauma to a structure. In this case the pain occurring from the repeated microtrauma is

localized on the lateral aspect of the knee.

Inversion. Inversion refers to the motion of the foot which causes the plantar surface of the foot to be tilted so that it faces more toward the midline of the body. This motion occurs in the frontal plane. (Root, 1971)

Eversion. Eversion refers to the motion of the foot which causes the plantar surface of the foot to be tilted so that it faces further away from the midline of the body. This motion occurs in the frontal plane. (Root, 1971)

Forefoot Valgus. Forefoot valgus refers to a twisted position of the foot in which the forefoot, in relation to the calcaneus, is angled away from the midline of the body. (Durland, 1965)

Forefoot Varus. Forefoot varus refers to a twisted position of the foot in which the forefoot, in relation to the calcaneus is angled toward the midline of the body. (Durland, 1965)

Tibial Varus. Tibial varus refers to a position of the leg in which the distal end of the tibia is angled toward the midline of the body. (Root, 1971)

Tibial Valgus. Tibial valgus refers to a position of the leg in which the distal end of the tibia is angled away from the midline of the body. (Root, 1971)

Dorsiflexion. Dorsiflexion is the motion involved in bringing the dorsal surface of the foot closer to the anterior surface of the

leg, thus decreasing the angle between the dorsum of the foot and the tibia.

Subtalar Joint. The subtalar joint is the juncture of the calcaneus and the talus.

Neutral Position of the Subtalar Joint. The subtalar joint is in neutral position when the alignment of the talus and calcaneus is such that neither the lateral nor the medial aspect of the talus is prominent. This position normally allows for the calcaneus to invert twice as many degrees as it everts. (Root, 1971)

Internal Rotation of the Lower Leg. Internal rotation of the lower leg was defined as the total number of degrees that the reference line on the anterior surface of the leg moved internally from zero on a protractor when 100 inch pounds of torque were applied to the leg.

External Rotation of the Lower Leg. External rotation of the lower leg was defined as the total number of degrees that the reference line on the anterior surface of the leg moved externally from the zero point on a protractor when 100 inch pounds of torque were applied to the leg.

Microtrauma. Microtrauma refers to submaximal stress or injury to a structure.

Delimitations

The study was delimited to 60 runners living in Bozeman, Montana. Forty-nine of the runners entered the 1979 Governor's Cup Race in Helena, Montana and ran either 10 kilometers, 20 kilometers or completed the 26 mile marathon course. Also included as subjects were 11 runners competing on the men's and women's cross country teams at Montana State University in the fall of 1979. This study considered runners that had experienced lateral knee pain in the past as well as those experiencing it presently. The study also included runners who had not experienced lateral knee pain in the past or presently.

Limitations

The study was limited by the number and availability of subjects that had experienced lateral knee pain. Subjects were tested throughout the day from November 28 through December 13, 1979 with no control over the exercise or activities in which they participated prior to testing, or the time of day. Also no control was placed on the type of running shoe worn, running surface or distance run in the subject's workout. Further there was no control placed on the subject's age, sex, height or weight.

Chapter 2

REVIEW OF RELATED LITERATURE

Literature Related to Overuse Syndromes

In a biomechanically correct running gait the foot strikes the ground supinated and the major portion of the weight lands on the lateral border of the heel. After contact the foot immediately pronates allowing for the absorption of the shock of landing. Following pronation the foot resupinates enabling the calcaneus to be perpendicular to the ground with the five metatarsal heads in contact with the running surface at the midstance phase of the running gait. The foot continues to supinate past the neutral position and becomes a rigid lever in order to propel the foot during the toe-off phase and still maintain a stable foot. (Aronson, 1977)

The degree to which each of these occurs according to Aronson (1977) determines the efficiency of the running stride and the incidence of injury. Any foot imbalance leads to the muscles functioning out of phase and eventual fatigue or injury due to inefficient movement.

James, Bates and Osternig (1978) indicated that 60 percent of all running problems are related to training errors. However they agreed that lower extremity alignment is an important consideration. This is based on three assumptions: 1) There is a position in which the foot functions most efficiently with the least amount of stress on supporting structures. 2) The foot during weight-bearing should be in such a

position that the plane of the metatarsal heads is perpendicular to the vertical axis of the calcaneus and the vertical axis of the calcaneus is parallel to the long axis of the distal one third of the tibia. (James, 1978) 3) These structural alignments should occur with the subtalar joint in neutral position.

James et. al. (1978) gave instructions for measuring the structural alignments mentioned. They also cited 180 patients and related the overuse syndromes described by the patients to the foot disorder they observed. They found the most common foot disorder to be pronated feet. Three main causes of overuse syndromes were discussed: training errors, anatomical factors, shoes and running surfaces. (James, 1978) James, Bates and Osternig advocated conservative methods of treatment in dealing with overuse syndromes. These methods were rest, reduced mileage, stretching, a change in shoes and orthotics.

The treatment of running injuries according to Mirkin (1976) should be prevention and the elimination of the four factors that cause them--overuse, lack of flexibility, abnormal foot structure and muscle function imbalance. Mirkin also indicated pronated feet as a potential problem as this is in many cases accompanied by low arches. He maintained that the low arches are not always due to a structural problem but many times due to a weak ankle that allows the foot to roll medially. When this happens an abnormal force is applied to the medial side of the ankle and therefore an

opposite force is transmitted to the lateral side of the patella and the lateral side of the knee. The author believes that Mirkin was suggesting that as the foot everts the alignments of the tibia and femur are changed. As a result of the change in alignment there is a decrease in the space between the tibia and femur on the lateral aspect as the two bones pinch together. This action applies stress to this area on the lateral aspect of the knee. Chrondromalcia patella and lateral band (illio-tibial band) syndrome are two overuse syndromes that could result from abnormal torque applied to the lateral side of the patella or the knee. An abnormal torque could also be transmitted to the lateral side of the hip with the potential result being pain localized at the hip. (Mirkin, 1976) Treatments suggested by the author included rest, increasing flexibility, podiatric evaluation, possibly orthotics and increasing strength to correct muscle imbalances. (Mirkin, 1976)

The efficiency of foot contact, midstance phase, toe-off and swing phases have a great deal of influence on performance and the ability to withstand stress according to Subotnick. Overstress leads to overuse syndromes and considering that a long distance runner running about 100 miles per week plants each foot approximately 3,000,000 times each year, overstress is a very real problem. (Subotnick, 1975) The author indicated that there was a need to investigate the relationships between foot function and overuse syndromes. He advocated varied workouts on

different surfaces and proper conditioning with emphasis on increasing flexibility and strengthening as a means of reducing stress. Subotnick also discussed normal foot function and the possible results from structural abnormalities. He suggested orthotics for treatment in the case of structural problems.

Subotnick (1977) in a later article again suggested that injuries in the lower extremity may originate at the foot. He explained that a neutral foot with a normal arch places the calcaneus perpendicular to the ground and could support the body weight without the assistance of the ligaments and muscles. If the foot is not neutral during the running gait, the muscles must overwork placing unnecessary stress on the structures of the leg. This unnecessary stress could lead to overuse injuries.

Subotnick cited the runner's knee as one of the most commonly seen overuse syndromes. He defined runner's knee as a combination of or any of the following: chrondromalcia patella, patellar compression, patellar subluxation, patellar tendonitis or a ligament problem. The author related these problems to improper foot function and in particular to abnormal pronation.

Treatment for runner's knee, the author explained, should consist of exercises to strengthen the muscles that stabilize the knee and possibly orthotics. No specific muscles or muscle groups were mentioned.

Marshall (1979) also supported the premise that foot, hip, leg,

knee and low back pain associated with overuse type injuries arise from a structural instability of the foot. He stated that if a portion of the foot is not functioning correctly, abnormal stresses are placed upon the supporting limb. Marshall discussed proper foot mechanics and then related improper foot mechanics to Morton's foot, heel spurs and shin splints. He indicated that most overuse syndromes are complicated by a lack of flexibility. As far as a treatment for overuse problems, Marshall suggested rest and orthotics. (Marshall, 1979)

Sheehan (1977) found that runners suffering from overuse syndromes usually have one of three structural problems. These include biomechanically weak feet, a leg length discrepancy or minor abnormalities of the lumbrosacral area. He added that training generally causes a strength/flexibility imbalance in the muscles. This can cause exaggerated pronation at foot strike and when coupled with a structural abnormality, can increase the potential for foot, leg or knee problems. The author indicated that running against traffic causes the right foot to be higher on the crown of the road than the left foot and therefore often forces exaggerated pronation of the right foot. Another cause of pronation of the foot can be orthotics that overcorrect. These various problems can cause pronation and therefore can all increase the incidence of injury. (Sheehan, 1977)

Henderson (1974) summarized a symposium at the California College of Podiatric Medicine concerning overuse syndromes. The focus was the

prevention of overuse injuries on the leg. Podiatrists have determined that 50 to 70 percent of the athletes studied have foot and leg alignment abnormalities. These alignment problems could lead to injuries if enough stress was applied. The author concluded that there were three factors important to consider in running. These included stress, muscle imbalance (flexibility and strength) and biomechanics. (Henderson, 1974)

Literature Related to Lateral Knee Pain

Mayfield (1977) related lateral knee pain to tendinitis of the popliteus tendon. He indicated that in the past five years this condition had been a frequent and increased cause of lateral knee pain particularly in those persons performing downhill activities on a regular basis. Mayfield discussed 30 patients that he saw over a five year period. He indicated that 14 had experienced only one episode of tendinitis, while seven had a reoccurrence of the pain upon resuming the activity that caused it. Seven were without relief of pain however, it was later found that five of those seven cases had pain which proved to be due to cartilage tears rather than tendinitis. Lateral knee pain manifests itself in pain localized on the lateral aspect of the knee and appears in varying degrees and lengths of duration. Mayfield felt that the function of downhill walking or running may cause increased stress on the popliteus muscle-tendon unit and therefore cause pain on the lateral aspect of the knee.

Stress to the popliteus muscle-tendon unit as a possible cause of pain can be supported by an explanation of the function of the popliteus muscle-tendon unit. The main function of the unit is to bring about and maintain the internal rotation of the tibia on the femur. (Mann, 1977) The rotation is initiated during the swing phase of the running gait and maintained during the stance phase. Mayfield indicated that this muscle-tendon unit also provides stability during flexion but most importantly must aid in keeping the femur from displacing anteriorly off the tibia during the stance phase of the normal running gait. (Mayfield, 1977)

Orava (1978) examined 88 patients all of whom were middle-aged joggers or active athletes involved in regular training. The symptom he observed was a stinging pain on the outer femoral condyle. The pain was most intense as the leg contacted the ground during the deceleration phase of running. Orava concluded that this pain was the result of the friction of the iliotibial tract over the lateral femoral condyle. He indicated conservative methods of treatment including proper warm-up, physiotherapy and local steroid injections. (Orava, 1978)

Bogdan (1978) examined, evaluated and treated 128 runners at the California College of Podiatric Medicine Sports Medicine Clinic. He found the most common complaint to be pain localized on the lateral aspect of the patella and knee joint. The most common foot disorder he observed was inversion of the foot with limited dorsiflexion at the

ankle when the knee was extended. It was not clear as to what degree of inversion of the foot was abnormal and whether it occured during weight-bearing or not. Bogdan related lateral knee pain to inversion of the foot explaining that the patella may slip laterally during heel contact causing pain due to stress on the lateral femoral condyle. He found most runner's knee complaints to be related to incorrect foot plant. Bogdan indicated that incorrect foot plant cuases that alignment of the knee joint to be functionally incorrect and as a result out of phase torquing between the femur and tibia. This in turn leads to poor shock absorption and pain. An abnormal torque would then be transmitted laterally up the weight-bearing limb. He recommended treatment with either rigid or soft orthotics. (Bodgdan, 1978)

Sheehan (1973) also related lateral knee pain to the patella slipping laterally due to improper foot function. Nine-hundred runners responded to a Runner's World poll concerning overuse injuries. Seventeen percent indicated that they suffered from knee pain severe enough to terminate their running. (Sheehan, 1973) Sheehan advocated a treatment for the knee problems should be directed at the foot and suggested shoe changes or possibly podiatric evaluation and orthotics. He also indicated that running surfaces as well as contour must be considered.

The literature reviewed related overuse syndromes to a variety of

causes and suggested many different treatments for relief of overuse syndromes. Several authors indicated that problems in the leg, knee, hip and even back can be attributed to abnormalities at the foot. Very few of these claims were supported with research data. The authors that substantiated their statements relied primarily on clinical observation.

Literature Related to Instrumentation

Osternig, Bates, James and Jones (no date) designed a method to determine knee rotary torque patterns. The subject was positioned in an adjustable rigid chair with the torso vertical and the hips and thighs secured with straps. The foot was fitted into a two piece boot which was designed to prevent inversion and eversion of the talocalcaneal joint. This method was used in conjunction with a Cybex Dynamometer to measure the torque generated by the subject. A test-retest reliability study was performed on the method with x-rays used to confirm the stability of the calcaneus. Osternig, Bates, James and Jones substantiated that they had successfully fixed the calcaneus during the testing. The researchers also found that the subjects reached peak torque within the first few degrees of tibial rotation both internally and externally. They discussed the implications of this method for comparing postsurgical and unoperated limbs. (Osternig, no date)

Lilletvedt (1976) employed the Phillips Biometer in an

investigation of the relationships between lower extremity alignments and the shin splint syndrome in 32 female athletes. Subjects were divided into six test groups. The results indicated that ten of the fifteen measurements taken varied significantly between the no shin splint group and the current shin splint group and between the no shin splint group and the previous shin splint group. Eleven of the fifteen measures varied significantly between the previous shin splint group and the current shin splint group.

The author found that six of the measurements taken could be used to predict the occurrence of the shin splint syndrome. These included the degree of internal rotation of the femur with the hip extended, the degree of external rotation of the femur with the hip extended, the degree of dorsiflexion of the ankle with the knee flexed and extended, the degree of inversion at the subtalar joint, the frontal plane position of the tibia/subtalar joint static, and the position of the calcaneus in relation to the floor/subtalar joint static.

Courtney (1977) conducted a study using the Phillip's Biometer to investigate the relationship between lower extremity alignment and Achilles Tendonitis syndrome. The 29 subjects were classified into three test groups. The author found a significant difference in the measures of eversion and the measures of dorsiflexion with the knee extended and the degree of external rotation of the femure with the hip flexed between the no Achilles Tendonitis group and the present

Achilles Tendonitis group.

Ferrandino (1977) conducted a study of the biomechanical and radiographic characteristics of the lower extremities of runners with Morton's Foot syndrome. The researcher employed the Phillip's Biometer, a thimble rule, a pedograph and x-rays in her examination of 46 runners. The subjects were classified into five test groups. Ferrandino found the degree of internal rotation of the femur with the hip extended, eversion of the subtalar joint and the degree of external rotation of the femur with the hip extended to be significantly related to pain in runners with an outwardly appearing long second toe.

Chapter 3

METHODS AND PROCEDURES

Subject Description and Classification

A list of entrants for the Governor's Cup Race held in Helena, Montana in June 1979 was obtained by the researcher. All of the individudals included on this list were contacted as potential subjects. Also contacted were the men and women competing on the varsity cross country teams at Montana State University in the fall of 1979. Each received a letter that explained the study as well as a response card. (Appendix A) All individuals who responded were contacted between November 26 and December 13, 1979 and those who agreed to be included in the study were scheduled for an appointment. Fifteen women and 45 men participated as subjects in this study. Ages ranged from 18 to 84 years, weights varied from 110 to 220 pounds and heights were recorded between five feet two inches to six feet four inches. Raw score distributions can be found in Appendix B.

Each leg of a single individual served as a separate subject. The 120 legs were divided into two categories: 1) those legs that had experienced lateral knee pain and 2) those legs that had not experienced lateral knee pain. Therefore it was possible for each leg of one subject to be classified into different groups.

Subjects that had experienced lateral knee pain as well as those who had not experienced lateral knee pain were accepted for the study.

Any limb that had surgery performed on it during the past five years was eliminated from the study.

Instrumentation

The researcher used two instruments to collect the data analyzed in this study. These were the Phillip's Biometer and the Inter-Ex I, an instrument developed by the researcher to measure the degree of internal and external rotation of the lower leg at the knee joint.

The Phillip's Biometer, developed by Phillips (1979) was used to obtain the measurements of lower extremity alignment, selected ranges of motion at the hip, knee and ankle joints and foot position during weight-bearing. (Figures 1-2) The methods employed in the use of the Phillip's Biometer were those described by Lilletvedt (1976).

The Inter-Ex I (Figure 3) consisted of a table with a protractor on it to mark the degrees of rotation. An axis of rotation went through the table and connected to a platform that was used as a base of support for the subject's foot. The foot was secured on this platform by two velcro straps, one surrounding the ankle and the other over the phalanges. Two adjustable metal braces slid in on either side of the foot to help stabilize it. The distal end of the axis of rotation was attached to two immovable arms to which a torque wrench was connected. The torque wrench was employed to determine the range of motion of internal and external rotation of the knee when a predetermined torque was applied.

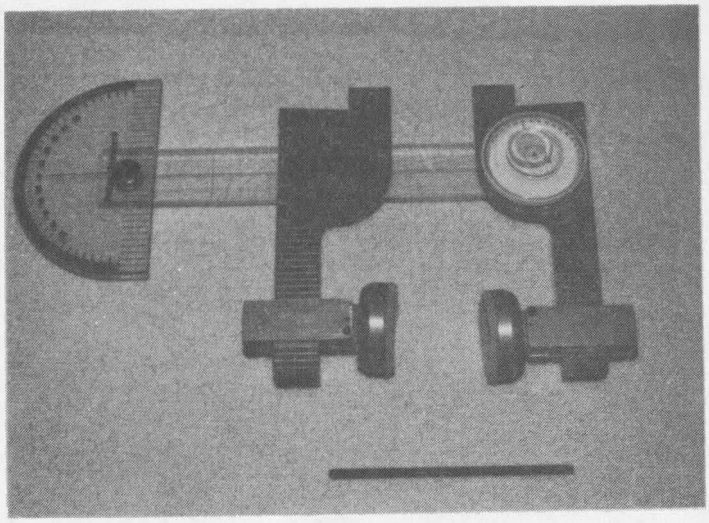

Figure 1: The Phillip's Biometer Assembled

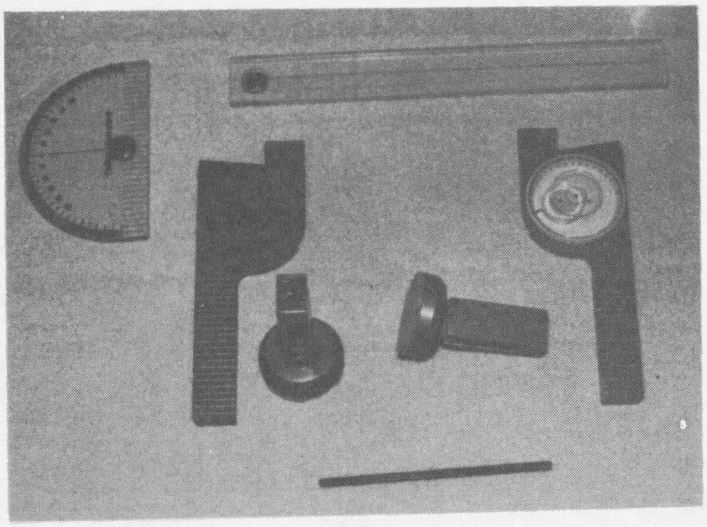

Figure 2: The Phillip's Biometer Disassembled

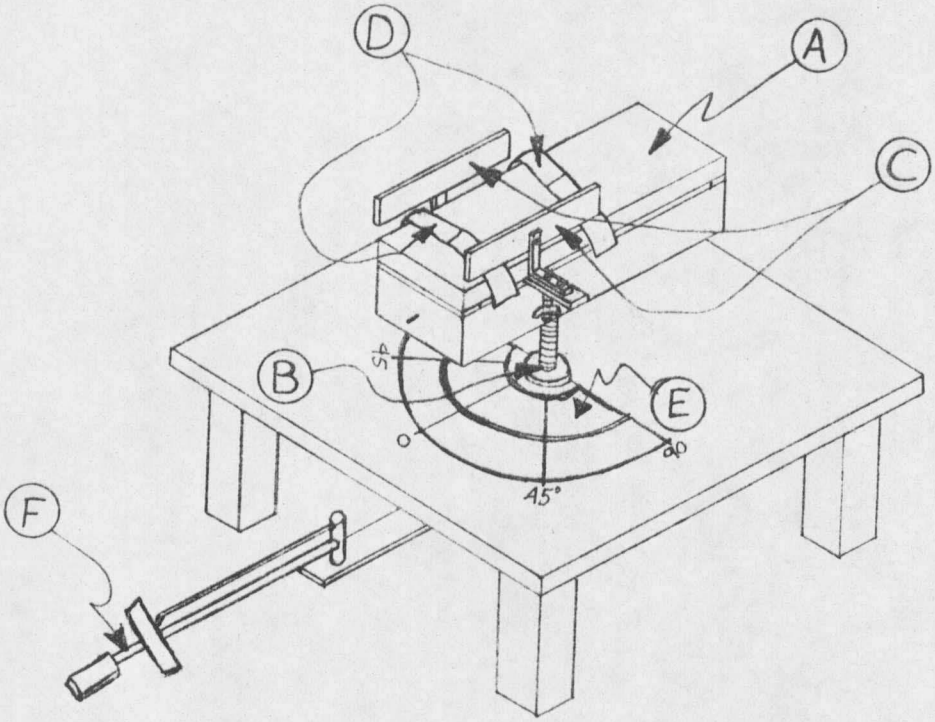

Figure 3: Inter-Ex I.

KEY

A - Foot Platform
B - Axis of Rotation
C - Foot Stabilizers
D - Velcro Straps
E - Protractor
F - Torque Wrench

A line bisecting the anterior surface of the leg was drawn as a reference point from which to take the measurement. A pilot study was undertaken to determine the appropriate amount of torque to apply for each movement. Ten subjects were tested with the Inter-Ex I in an attempt to determine the amount of torque that could be applied in each direction of motion without eliciting pain. The lower limit of pain was found for each of the ten subjects tested and a torque just below the average lower limit of pain selected. In this manner it was determined that 100 inch pounds of torque would be applied to each lower extremity measured in each direction.

The validity of the Phillip's Biometer and the Inter-Ex I was accepted on face validity as it was felt that each instrument measured what it was employed to measure.

Data Collection Techniques

The measurements of forefoot valgus and varus selected ranges of motion at the hip, knee, ankle and subtalar joints and foot position during weight-bearing were taken by the researcher with the Phillip's Biometer. More specifically the investigator measured the degrees of inversion and eversion of the calcaneus in relation to the leg, the degrees of forefoot valgus or varus, the degrees of dorsiflexion of the foot with the knee extended and flexed, the degrees of flexibility of the hamstring muscle group with the hip flexed, the degrees of

external and internal rotation at the hip with the hip extended and flexed, the static stance position of the calcaneus, the tibial stance position, the calcaneal position with the subtalar joint in neutral position and the tibial stance position with the subtalar joint in neutral position. The measurements taken were those described by Lilletvedt (1976). The scores were recorded by the researcher on the Podiatrics Incorporated Examination Chart. (Appendix C)

The researcher undertook a pilot study in March 1979 in order to ensure the reliability in the use of the Phillip's Biometer. Ten subjects were tested and retested and scores statistically analyzed. The correlation coefficients indicated significant researcher reliability ($p<.05$) in nine of the twelve measurements including:

1. inversion and eversion of the calcaneus in relation to the leg
2. the degrees of forefoot valgus and varus
3. the degrees of dorsiflexion of the foot with the knee extended
4. the degrees of dorsiflexion of the foot with the knee flexed
5. the degree of flexibility of the hamstring muscle group
6. the degree of internal and external rotation at the hip with the hip extended
7. the degree of internal and external rotation at the hip with the hip flexed
8. the tibial stance position

9. the calcaneal position with the subtalar joint in neutral position

The researcher proved unreliable in two of the measurements, the static stance position and the tibial stance position with the subtalar joint in neutral position. This was due to the inclusion of zeros in the raw data. Zeros could not be analyzed by the program used and therefore were disregarded. The dismissal of zeros from the data in turn caused a low degree of reliability at the .05 level of significance. This was also a factor in the measurement of the tibial stance position and the calcaneal position with the subtalar joint in neutral position, as indicated by the correlation coefficients for these two measurements. (Appendix D)

Degrees of internal and external rotation of the lower leg were measured by the use of the Inter-Ex I. The subject was instructed to sit with knees flexed at the edge of the examination table while the foot was placed in the instrument and secured with the velcro straps. While the subject actively maintained the knee in position, 100 inch pounds of torque were applied to the foot, rotating the leg internally and then externally.

Measurements were recorded in degrees. The measurement was defined as the number of degrees on a protractor that a reference line on the anterior surface of the leg moved from zero. A T-square was used to sight the measurement on the protractor from the top of the reference line. (Figures 4-8)

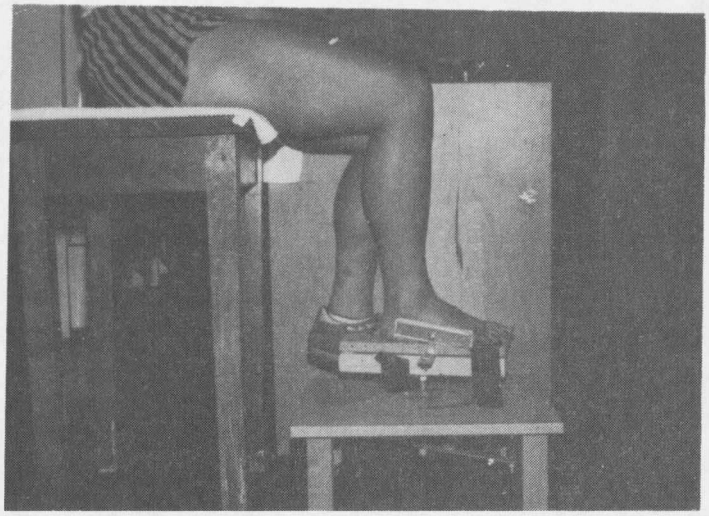

Figure 4: Examination position for Inter-Ex I
Subject seated on table with knee flexed to 90°

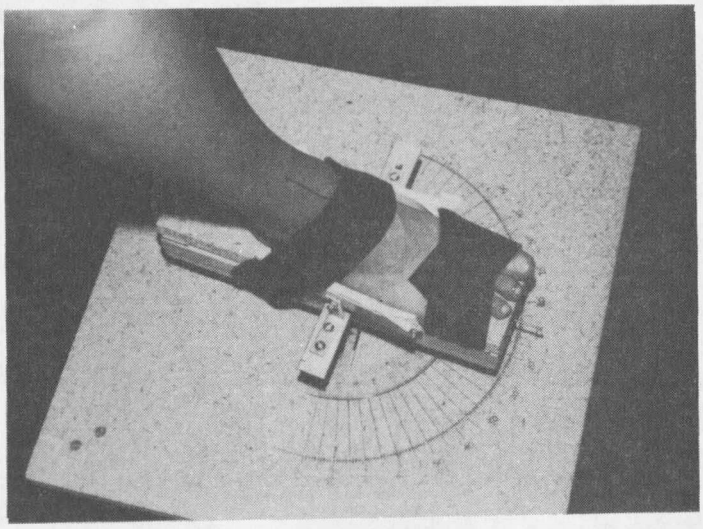

Figure 5: Foot secured with velcro straps and metal braces
in the Inter Ex-I

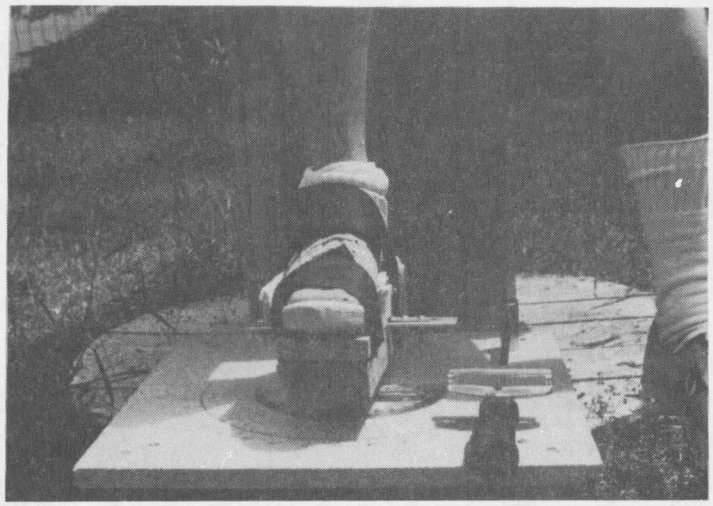

Figure 6: Foot secured on platform of Inter-Ex I (front view)

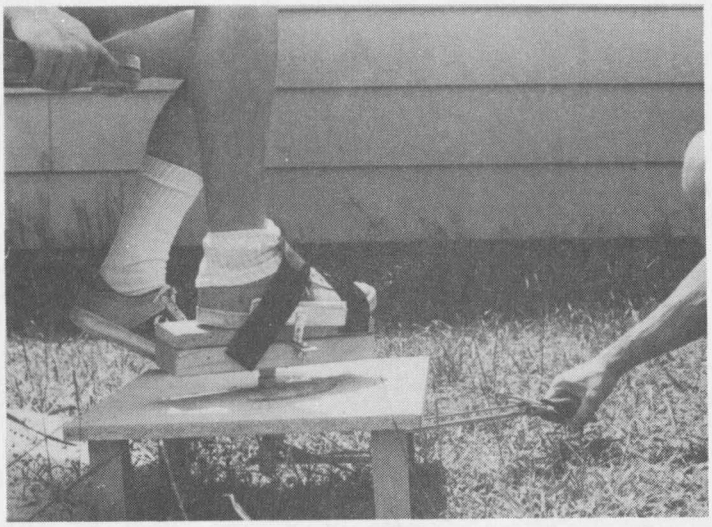

Figure 7: Internal rotation of the lower leg with the Inter-Ex I.

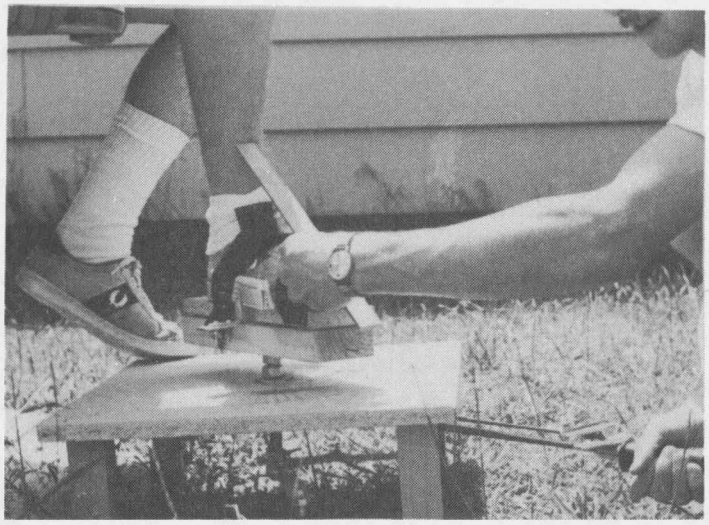

Figure 8: Measurement of external rotation of the lower leg with the Inter-Ex I.

Distributions of the raw scores were taken for each of the 22 measures to determine whether or not there were any abnormal distributions that would statistically bias this study. All distributions were found to be statistically normal. (Appendix E)

Additional data were collected through the use of a questionnaire. (Appendix F) The measurements of the runners that had experienced lateral knee pain were statistically compared to the measurements of the runners that had not experienced lateral knee pain to determine if a relationship existed between any of the lower extremity measurements taken by the researcher and the occurrence of lateral knee pain. Also compared were the lower extremity alignments of the two groups to

determine if the populations involved could be described in terms of their lower extremity alignments.

An analysis of variance was performed on the data acquired from the questionnaire. This data included height, weight, sex, age, number of days per week that the subject ran, miles per day, most common running surface, most commonly worn shoe brand, and the number of years that the subject had been running. An analysis of variance showed no significant difference ($p<.05$) between any of the nine variable acquired through the use of the questionnaire between those runners who had experienced lateral knee pain and those runners who had not experienced lateral knee pain.

Chapter 4

RESULTS

In order to test the null hypothesis that there would be no significant difference in the lower extremity alignment as described by the measures of forefoot valgus and varus, selected ranges of motion at the hip, knee, ankle and subtalar joints and foot position during weight-bearing, between those persons that had experienced lateral knee pain and those persons that had not experienced lateral knee pain an analysis of variance was performed on the data. The results of the analysis of variance can be found in Table 1.

Table 1: Summary of the Analysis of Variance

Source	D.F.	S.S.	M.S.	F
Knee Pain	1	25.28	25.28	.486
Variables	21	888672.68	42317.74	812.767***
Knee Pain x Variable	21	1949.73	92.844	1.783***
Remainder	2596	135164.0	52.066	

***Significant ($p<.05$), critical value = 1.57

The analysis of variance indicated that there was a significant difference between the lower extremity alignment of those persons that had experienced lateral knee pain and those persons that had not experienced lateral knee pain ($p<.05$). These results also indicated that each group tested came from a different population and therefore could

be described in terms of lower extremity alignment and range of motion. Therefore the alternate hypothesis was accepted.

Specific Measurement Differences

Since an analysis of variance indicated that the two test groups were significantly different, a Duncan's Multiple Comparison was applied to the means of each of the measurements taken, in order to determine which of the means of the measures were significantly different between the two test groups. The results of the Duncan's Multiple Comparison are shown in Table 2.

Two of the 22 measurements were significantly different between the group that had experienced lateral knee pain and the group that had not experienced lateral knee pain ($p < .05$). Those runners that had experienced pain showed significantly less hamstring muscle group flexibility as measured by range of motion at the knee with the hip flexed to 90° than the runners who had not experienced lateral knee pain. Also, those runners who had experienced lateral knee pain showed a lesser degree of internal rotation of the lower leg. This was not true for the runners that had not experienced lateral knee pain. All other measurements showed no significant difference between the two test groups at the .05 level of significance. Therefore the alternate hypothesis was accepted.

Table 2: Summary of the Duncan's Multiple Comparison

Measurement	Least Mean Square No Knee Pain (in degrees)	Least Mean Square Knee Pain (in degrees)	Difference Between Means (in degrees)
Eversion	4.3	4.5	-.2
Inversion	12.6	12.2	.4
Dorsiflexion-knee extended	18.2	16.6	1.6
Dorsiflexion-knee flexed	17.8	17.3	.5
Hamstring flexibility	18.8	24.6	-5.8***
External hip rotation hip extended	60.2	60.9	-.7
Internal hip rotation hip extended	36.3	35.8	.5
External hip rotation hip flexed	54.3	53.4	.9
Internal hip rotation hip flexed	37.2	35.5	1.7
Calcaneal stance-inverted	.75	.38	.37
Calcaneal stance-everted	1.8	1.6	.2
Tibial stance-varum	6.2	5.5	.7
Tibial stance-valgum	.05	.00	.05

Table 2: Summary of the Duncan's Multiple Comparison (Continued)

Measurement	Least Mean Square No Knee Pain (in degrees)	Least Mean Square Knee Pain (in degrees)	Difference Between Means (in degrees)
Corrected calcaneal inverted	1.0	.64	.36
Corrected calcaneal everted	.43	.64	-.21
Corrected tibial-varum	4.4	3.64	.76
Corrected tibial-valgum	.15	.129	.021
Internal leg rotation	32.8	28.67	4.13***
External leg rotation	40.0	42.2	-2.2

***Duncan's Multiple Comparison Significant ($p<.05$)

Explanation of Forefoot Valgus and Varus

All possible combinations of forefoot valgus and varus for the right and left feet were analyzed by the Duncan's Multiple Comparison. The conditions were categorized into four combinations which included:

1 = left foot varus, right foot varus

2 = left foot varus, right foot valgus

3 = right foot varus, left foot valgus

4 = left foot valgus, right foot valgus

The mean score for the conditions of the groups experiencing lateral knee pain was 2.4 while the mean score for the group with no knee pain was recorded at 2.1 leaving a difference between the means of -.3. Therefore no significant difference ($p<.05$) was found between the pain and the no pain groups for the right and left foot forefoot valgus and varus conditions.

Chapter 5

DISCUSSION OF RESULTS

In the past few years many authorities have related a variety of overuse syndromes to lower extremity alignment. It has been suggested that foot plant and leg alignment may increase the vulnerability to overuse injuries of the leg, however little research has been done in this area.

This study looked at the relationship between lower extremity alignment and selected ranges of motion at the hip, knee, ankle and subtalar joints and the incidence of lateral knee pain in runners. It was found that limited internal rotation of the lower leg and hamstring inflexibility were significantly different between the runners who had experienced lateral knee pain and the runners who had not experienced lateral knee pain.

Several authors (Mirkin, 1976; Subotnick, 1975; Sheehan, 1977) cited a lack of flexibility as a contributing factor in running injuries. It was reasoned that by increasing flexibility, stress could be reduced and therefore overuse injuries may be reduced. The results of this study supported these statements indicating that hamstring inflexibility related to lateral knee pain.

In a biomechanically correct running gait, the runner approaches extension at heel strike (163.6°) and during the midstance phase. Bates et. al., no date) A runner with inflexible hamstrings does not extend the leg to the same degree as a runner with more flexible hamstrings.

Therefore this runner may be running with the knees flexed to a greater degree than what is considered efficient. A runner heading downhill also runs with knees flexed to ensure balance. Therefore it would appear that the runner with inflexible hamstrings is always running as though he/she was running downhill.

Mayfield (1977) indicated that many cases of lateral knee pain appeared in persons who were involved in downhill running or walking on a regular basis. He explained that in these types of activities the popliteus muscle-tendon unit keeps the femur from displacing anteriorly off the tibia. The author failed to consider the cruciate ligaments whose primary functions is stabilizing the femur on the tibia.

Considering this function of the popliteus it is evident that a runner with inflexible hamstrings, running as though he/she were running downhill continuously could put a great amount of stress on the popliteus muscle. In light of the fact that the popliteus muscle originates on the lateral condyle of the femur it would be possible for stress on this muscle-tendon unit to cause lateral knee pain.

Inflexible hamstrings also relates to the second significant variable, a limited degree of internal rotation of the lower leg. Should the lateral side of the hamstring muscle group, i.e. the biceps femoris, be inflexible it would not allow for internal rotation of the lower leg.

During the swing phase of the running gait internal rotation is initiated and should be maintained during the stance phase (Mayfield,

1977). Therefore a limited degree of internal rotation of the lower leg could place the foot in an improper alignment (i.e. toeing out) at the beginning of the stance phase. Orava (1978) found that lateral knee pain was most intense at the time when the foot contacted the ground at heel strike--the beginning of the stance phase.

It was found that 11 cases of lateral knee pain differed from the results of the study. These 11 cases had internal rotation of the lower leg measures which were at least one standard deviation higher than the mean score for that measurement. Perhaps in these individuals the dominant factor in the onset of pain was hamstring inflexibility. In these cases the inflexible hamstrings would possibly be due to the medial side of the muscle group, i.e. the semimembranosus and semitendinosus.

In this study the degrees of internal rotation were determined through passive rotation of the lower leg. Thus the torque applied was held constant. More information concerning the lateral knee pain may be disclosed if the torque produced by internal and external rotators of the knee were recorded. Internal rotation would indicate the torque produced by the semimembranosus, semitendinosus and popliteus, while external rotation would show the torque produced by the biceps femoris. It would also be beneficial to include the measurement of the torque produced by the quadricep muscle group and to make comparisons between this measurement and the measurement of torque produced by the

hamstring muscle group.

In view of the two factors, hamstring inflexibility and a limited degree of internal rotation of the lower leg, which have been found to relate to lateral knee pain in this study, several suggestions can be made. First, runners experiencing pain should employ various stretching techniques in an attempt to increase the flexibility of the hamstring muscle group. Care should be taken to maintain a neutral position of the foot during stretching. This is necessary because an internally rotated knee during the stretching of the hamstrings stretches primarily the lateral side of the hamstring muscle group while externally rotating the knee during stretching of the hamstrings focuses on the medial side of the hamstring muscle group. The neutral foot allows for equal stretching for the entire muscle group and therefore is most beneficial in alleviating pain.

Increasing flexibility of the hamstrings can also aid in increasing the degree of internal rotation of the lower leg. In particular increasing the flexibility of the lateral side of the hamstring muscle group, the external rotator of the lower leg can help to increase internal rotation of the leg, i.e. the biceps femoris. Strengthening the internal rotators of the leg, i.e. the semimembranosus, semitendinosus and popliteus would also aid in increasing the degree of internal rotation of the lower leg.

Chapter 6

SUMMARY, CONCLUSIONS, RECOMMENDATIONS

Summary

The purpose of this study was to determine whether or not a relationship existed between the lower extremity alignment of runners and the incidence of lateral knee pain. Further the study attempted to disclose whether or not any of the specific measurements taken were significantly different between the runners who had experienced lateral knee pain and the runners who had not experienced lateral knee pain. Finally the study attempted to determine whether or not the samples came from different populations which could be identified in terms of their lower extremity alignments.

The lower extremities of 60 runners were measured with the Phillip's Biometer and the Inter-Ex I. Lower extremity alignment measures, selected ranges of motion at the hip, knee, ankle and subtalar joints and foot position during weight-bearing were recorded for each subject and statistically analyzed. An analysis of variance as well as a Duncan's Multiple Comparison was applied to the data.

The analysis of variance showed a significant difference ($p<.05$) between the lower extremity alignments of the runners who had experienced lateral and the runners who had not experienced lateral knee pain. Therefore a Duncan's Multiple Comparison was applied to the data. The results of the Duncan's Multiple Comparison indicated that

hamstring flexibility and the degree of internal rotation of the lower leg were significantly related to lateral knee pain in runners.

Conclusions

Based on the results of this study the following conclusions were made. The results showed that limited hamstring flexibility and a limited degree of internal rotation of the lower leg were significantly related to lateral knee pain in runners ($p<.05$).

Recommendations

The results of this study were found to be significant, however several recommendations can be made for further research in this area. These recommendations include:

1. The study could be repeated with a larger number of subjects to increase the validity of the results.
2. The study could be repeated employing people involved in downhill locomotor activities (e.g. mountaineers) to substantiate the results of this study.
3. The study could be repeated utilizing a Cybex Dynamometer to include comparisons of muscle group torque differences as a variable.
4. The study could be repeated including cinemagraphic data of the running gait to support the results of the study.

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APPENDIXES

APPENDIX A

MSU DEPARTMENT OF HEALTH, PHYSICAL EDUCATION & RECREATION

COLLEGE OF EDUCATION MONTANA STATE UNIVERSITY, BOZEMAN 59717

Janice E. Flood
414 South 12 Avenue
Bozeman, MT 59715
587-4989

Dear

I am a graduate student at Montana State University and am currently working on a thesis. The topic of my study is lateral knee syndrome, a condition commonly plaguing people engaging in downhill activities. This overuse syndrome manifests itself in pain to the lateral (outside) aspect of the knee.

In an attempt to find factors related to this pain, I am hoping to examine at least thirty lower extremities affected by this condition and thirty not affected. I will be taking thirteen measurements which deal with foot position during weight bearing, lower extremity alignment and certain range of motion (flexibility) of the lower leg. These measurements will be accomplished through the use of the Phillips Biometer. Through statistical analysis, I hope to find several common characteristics of the limbs affected by lateral knee syndrome.

I am interested in testing serious runners with and without lateral knee pain. Therefore I have chosen Bozeman residents who ran in the Governor's Cup Race last June as potential subjects. If you are interested in becoming a subject for my study, please fill out the enclosed post card and return it to me by November 9, 1979. The testing will be done in approximately a thirty minute appointment that can be scheduled at your convience. I will contact you as to the time and date of your appointment should you be interesad in participating.

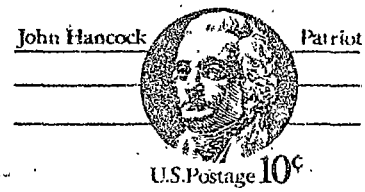
Thank-you,

Janice E. Flood

Ellen Kreighbaum

Ellen Kreighbaum Ph.D.
Professor and Director
of the Biomechanics Laboratory

TELEPHONE (406) 994 4001



Janice E Flood
414 South 12 Avenue
Bozeman, MT 59715

Name_____ Phone_____

Address_____

Preferred day(s) of the week_____

Preferred time of day_____

Lateral knee pain? yes_____ no_____

APPENDIX B

Raw Score Distributions

AGE, N=60

Raw Score (years)	RS Distribution Count	Percent
18	3	5.0
19	2	3.3
20	8	13.3
21	4	6.7
22	3	5.0
23	1	1.7
24	1	1.7
25	5	8.3
26	8	13.3
27	1	1.7
28	1	1.7
29	1	1.7
30	1	1.7
32	2	3.3
33	1	1.7
34	3	5.0
36	2	3.3
38	1	1.7
39	1	1.7
41	1	1.7
42	1	1.7
44	1	1.7
45	1	1.7
46	1	1.7
48	1	1.7
58	2	3.3
64	1	1.7
65	1	1.7
84	1	1.7

SEX, N=60

Raw Score	RS Disbribution Count	Percent
Female	15	25.0
Male	45	75.0

WEIGHT, N=60

Raw Score (pounds)	RS Distribution Count	Percent
110	10	16.7
120	3	5.0
130	5	8.3
140	10	16.7
150	13	21.7
160	13	21.7
170	4	6.7
200	1	1.7
220	1	1.7

Raw Score (days/wk)	RS Distribution Count	Percent
3	6	10.0
4	11	18.3
5	14	23.3
6	9	15.0
7	20	33.3

HEIGHT, N=60

Raw Score (inches)	RS Distribution Count	Percent
62	3	5.0
63	2	3.3
64	3	5.0
65	1	1.7
66	7	11.7
67	3	5.0
68	4	6.7
69	7	11.7
70	5	8.3
71	9	15.0
72	6	10.0
73	6	10.0
74	1	1.7
75	1	1.7
76	1	1.7
77	1	1.7

Raw Score (Miles/Day)	RS Distribution Count	Percent
2	6	10.2
3	3	5.1
4	9	15.3
5	7	11.9
6	9	15.3
7	7	11.9
8	8	13.6
9	4	6.8
10	3	5.1
12	1	1.7
13	1	1.7
19	1	1.7

APPENDIX C

EXAMINATION CHART

FOR MEASUREMENTS TAKEN WITH THE PHILLIPS BIOMETER

NAME _____

CASE NUMBER _____

AGE_____ WEIGHT_____ HEIGHT_____

EXAMINER _____

	LEFT		RIGHT	SUBTALAR JOINT
I	O	EVERSION	O	SUPINATION
II	O	INVERSION	O	PRONATION
	O		O	TOTAL R.O.M.
	O	VARUS / VALGUS	O	NEUTRAL POSITION

				MIDTARSAL JOINT
III	O	VARUS / VALGUS	O	

	EVALUATION
IIIa	1st to 5th Ray

				ANKLE JOINT	
IV	O	DORSIFLEXION / PLANTARFLEXION	O	RANGE OF DORSIFLEXION	KNEE EXTENDED
V	O	DORSIFLEXION / PLANTARFLEXION	O	RANGE OF DORSIFLEXION	KNEE FLEXED

			HAMSTRING
VI	O	KNEE FLEXORS	O

	c̄ HIP EXTENDED	c̄ HIP FLEXED	c̄ HIP EXTENDED	c̄ HIP FLEXED	HIP JOINT
VII	O	O	O	O	RANGE OF EXTERNAL ROTATION
VIII	O	O	O	O	RANGE OF INTERNAL ROTATION
	O	O	O	O	TOTAL R.O.M.
	O	O	O	O	NEUTRAL POSITION

				ANKLE TO KNEE
IX	O	INTERNAL / EXTERNAL	O	MALLEOLAR TORSION
	O	INTERNAL / EXTERNAL	O	ABNORMAL TRANSVERSE KNEE ROTATION

				STANCE CORRELATION
X	O	INVERTED / EVERTED	O	CALCANEAL STANCE POSITION IN STATIC ANGLE OF GAIT
XI	O	VARUS / VALGUS	O	FRONTAL PLANE POSITION OF TIBIA c̄ SUBTALAR JT STATIC POSITION
XII	O	INVERTED / EVERTED	O	CALCANEAL POSITION TO FLOOR c̄ SUBTALAR JOINT NEUTRAL
XIII	O	VARUS / VALGUS	O	FRONTAL PLANE POSITION OF TIBIA c̄ SUBTALAR JT NEUTRAL
	O	ABDUCTION / ABDUCTION	O	ANGLE OF GAIT
	O	PRONATION / SUPINATION	O	RESULTANT ABNORMAL SUBTALAR JOINT POSITION

GAIT ANALYSIS

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PROGRESS ANALYSIS

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APPENDIX D

Reliability Study

Correlation Coefficients	
Inversion of the calcaneus in relation to the leg	.81234*
Eversion of the calcaneus in relation to the leg	.85023*
Forefoot valgus or varus	.89877*
Dorsiflexion with the knee extended	.94709*
Dorsiflexion with the knee flexed	.86223*
Hamstring flexibility	.96736*
External rotation of the hip with the hip extended	.96542*
Internal rotation of the hip with the hip extended	.94636*
External rotation of the hip with the hip flexed	.97252*
Internal rotation of the hip with the hip flexed	.98538*
Static stance of the calcaneus	.25829
Tibial stance	.71565*
Static stance of the calcaneus with the subtalar joint in neutral position	.72008*
Tibial stance with the subtalar joint in neutral position	.28868

*Significant (p .05), critical value = .632

APPENDIX E

Raw Score Distributions for Each Individual Measurement

Eversion - left foot, N=59

Raw Score (degrees)	RS Distribution Count	Percent
1	6	10.2
2	7	11.9
3	7	11.9
4	9	15.3
5	9	15.3
6	7	11.9
7	5	8.5
8	4	6.8
10	3	5.1
11	1	1.7
14	1	1.7

Eversion - right foot, N=60

Raw Score (degrees)	RS Distribution Count	Percent
1	9	15.0
2	12	20.0
3	12	20.0
4	9	15.0
5	5	8.3
6	2	3.3
7	3	5.0
8	4	6.7
9	1	1.7
12	1	1.7
14	1	1.7
15	1	1.7

Inversion - left foot, N=60

Raw Score (degrees)	RS Distribution Count	Percent
3	1	1.7
4	4	6.7
5	2	3.3
6	3	5.0
7	3	5.0
8	7	11.7
9	6	10.0
10	4	6.7
11	5	8.3
12	4	6.7
14	6	10.0
15	1	1.7
16	2	3.3
17	1	1.7
18	4	6.7
19	3	5.0
21	1	1.7
22	2	3.3
24	1	1.7

Inversion - right foot, N=60

Raw Score (degrees)	RS Distribution Count	Percent
3	1	1.7
6	4	6.7
7	3	5.0
8	4	6.7
9	3	5.0
10	4	6.7
11	6	10.0
12	1	1.7
13	3	5.0
14	2	3.3
15	5	8.3
16	6	10.0
17	4	6.7
18	4	6.7
19	5	8.3
20	2	3.3
21	1	1.7
22	2	3.3

Forefoot Varus - left foot, N=34

Raw Score (degrees)	RS Distribution Count	Percent
1	6	17.6
2	5	14.7
3	7	20.6
5	3	8.8
6	5	14.7
7	2	5.9
8	2	5.9
9	4	11.8

Forefoot Varus - right foot, N=33

Raw Score (degrees)	RS Distribution Count	Percent
1	8	24.2
2	6	18.2
3	5	15.2
4	4	12.1
5	5	15.2
7	2	6.1
8	3	9.1

Forefoot Valgus - left foot, N=26

Raw Score (degrees)	RS Distribution Count	Percent
1	3	11.5
2	8	30.8
3	3	11.5
4	7	26.9
5	1	3.8
6	2	7.7
7	1	3.8
9	1	3.8

Forefoot Valgus - right foot, N=27

Raw Score (degrees)	RS Distribution Count	Percent
1	2	7.4
2	4	14.8
3	2	7.4
4	8	29.6
5	1	3.7
6	4	14.8
7	1	3.7
8	1	3.7
9	4	14.8

Dorsiflexion at the ankle with the knee extended - left leg
N=60

Raw Score (degrees)	RS Distribution Count	Percent
2	1	1.7
3	1	1.7
5	2	3.3
8	2	3.3
9	1	1.7
10	2	3.3
11	3	5.0
12	4	6.7
13	4	6.7
14	4	6.7
15	4	6.7
16	6	10.0
17	2	3.3
18	2	3.3
19	3	5.0
20	2	3.3
21	2	3.3
22	1	1.7
23	2	3.3
24	3	5.0
25	4	6.7
28	3	5.0
30	1	1.7
32	1	1.7

Dorsiflexion at the ankle with the knee extended - right leg
N=60

Raw Score (degrees)	RS Distribution Count	Percent
3	1	1.7
5	2	3.3
9	1	1.7
10	3	5.0
11	3	5.0
13	4	6.7
14	5	8.3
15	3	5.0
16	6	10.0
18	3	5.0
19	3	5.0
20	3	5.0
21	3	5.0
22	4	6.7
23	2	3.3
24	1	1.7
25	5	8.3
26	3	5.0
27	2	3.3
30	2	3.3
33	1	1.7

Dorsiflexion at the ankle with the knee flexed - left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
4	1	1.7
6	3	5.0
7	2	3.3
8	2	3.3
9	4	6.7
10	1	1.7
11	6	10.0
12	2	3.3
14	2	3.3
15	3	5.0
16	1	1.7
18	2	3.3
19	1	1.7
20	8	13.3
21	4	6.7
22	1	1.7
23	2	3.3
24	2	3.3
25	4	6.7
26	2	3.3
29	2	3.3
31	3	5.0
35	1	1.7
36	1	1.7

Dorsiflexion at the ankle with the knee flexed - right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
4	2	3.3
5	1	1.7
7	2	3.3
8	1	1.7
9	2	3.3
10	5	8.3
11	5	8.3
12	2	3.3
14	3	5.0
15	5	8.3
16	1	1.7
17	2	3.3
20	7	11.7
21	4	6.7
22	2	3.3
24	5	8.3
25	5	8.3
27	1	1.7
29	1	1.7
30	3	5.0
36	1	1.7

Hamstring muscle group flexibility - left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
1	1	1.7
2	1	1.7
4	2	3.3
5	2	3.3
6	1	1.7
8	1	1.7
9	2	3.3
10	1	1.7
13	1	1.7
14	4	6.7
15	4	6.7
16	2	3.3
17	2	3.3
18	1	1.7
19	2	3.3
20	1	1.7
21	2	3.3
22	5	8.3
24	3	5.0
25	2	3.3
26	1	1.7
28	1	1.7
29	1	1.7
30	3	5.0
32	2	3.3
33	1	1.7
34	1	1.7
35	2	3.3
40	2	3.3
41	1	1.7
42	2	3.3
46	1	1.7
48	1	1.7
52	1	1.7

Hamstring muscle group flexibility - right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
2	1	1.7
3	2	3.3
5	2	3.3
6	1	1.7
8	2	3.3
9	1	1.7
10	2	3.3
11	1	1.7
12	2	3.3
13	1	1.7
14	2	3.3
15	4	6.7
16	1	1.7
17	2	3.3
18	2	3.3
19	4	6.7
20	2	3.3
21	2	3.3
22	2	3.3
23	2	3.3
24	1	1.7
26	2	3.3
27	2	3.3
28	2	3.3
30	2	3.3
31	3	5.0
32	1	1.7
33	1	1.7
34	1	1.7
35	1	1.7
40	2	3.3
45	1	1.7
49	1	1.7
50	2	3.3

External rotation at the hip with the hip extended - left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
34	1	1.7
41	1	1.7
43	1	1.7
44	1	1.7
45	2	3.3
46	3	5.0
47	1	1.7
48	2	3.3
49	1	1.7
50	1	1.7
51	4	6.7
52	1	1.7
53	3	5.0
54	2	3.3
55	1	1.7
56	6	10.0
57	3	5.0
58	2	3.3
59	3	5.0
60	4	6.7
61	2	3.3
62	1	1.7
64	2	3.3
65	1	1.7
66	2	3.3
67	1	1.7
68	1	1.7
76	1	1.7
77	1	1.7
81	1	1.7
82	3	5.0
83	1	1.7

External rotation at the hip with the hip extended - right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
15	1	1.7
44	1	1.7
46	1	1.7
49	2	3.3
50	3	5.0
52	1	1.7
53	1	1.7
54	1	1.7
55	1	1.7
56	3	5.0
67	2	3.3
58	1	1.7
59	2	3.3
60	4	6.7
61	1	1.7
62	4	6.7
63	1	1.7
64	1	1.7
65	4	6.7
66	1	1.7
67	1	1.7
68	2	3.3
69	2	3.3
70	1	1.7
71	5	8.3
72	3	5.0
75	2	3.3
78	1	1.7
80	3	5.0
81	1	1.7
82	1	1.7
85	1	1.7
92	1	1.7

Internal rotation at the hip with the hip extended - left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
11	1	1.7
16	1	1.7
19	2	3.3
20	2	3.3
22	1	1.7
23	5	8.3
24	3	5.0
27	1	1.7
29	1	1.7
30	2	3.3
31	1	1.7
32	3	5.0
33	2	3.3
34	1	1.7
35	2	3.3
36	2	3.3
37	5	8.3
38	3	5.0
39	2	3.3
41	4	6.7
42	1	1.7
43	2	3.3
45	1	1.7
46	2	3.3
47	1	1.7
48	1	1.7
49	1	1.7
51	2	3.3
53	1	1.7
56	1	1.7
59	2	3.3
64	1	1.7

Internal rotation at the hip with the hip extended - right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
18	1	1.7
19	1	1.7
20	1	1.7
21	4	6.7
22	1	1.7
24	1	1.7
25	1	1.7
26	1	1.7
30	3	5.0
31	3	5.0
32	1	1.7
33	4	6.7
34	4	6.7
35	2	3.3
36	3	5.0
37	5	8.3
38	1	1.7
39	3	5.0
40	2	3.3
41	1	1.7
42	2	3.3
44	2	3.3
45	1	1.7
46	3	5.0
47	3	5.0
48	1	1.7
51	1	1.7
55	1	1.7
56	1	1.7
57	1	1.7
66	1	1.7

External rotation at the hip with the hip flexed - left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
30	1	1.7
34	2	3.3
35	2	3.3
37	1	1.7
38	1	1.7
39	1	1.7
40	1	1.7
42	2	3.3
43	1	1.7
44	2	3.3
45	2	3.3
46	4	6.7
48	3	5.0
49	2	3.3
50	3	5.0
51	5	8.3
52	4	6.7
54	2	3.3
55	2	3.3
56	4	6.7
58	1	1.7
59	1	1.7
60	1	1.7
61	2	3.3
62	1	1.7
64	3	5.0
65	2	3.3
66	3	5.0
67	1	1.7

External rotation at the hip with the hip flexed - right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
25	1	1.7
32	1	1.7
40	1	1.7
41	1	1.7
45	1	1.7
46	4	6.7
47	2	3.3
48	2	3.3
49	1	1.7
50	2	3.3
51	1	1.7
52	2	3.3
53	2	3.3
54	1	1.7
55	3	5.0
56	5	8.3
57	1	1.7
58	1	1.7
59	2	3.3
60	4	6.7
61	2	3.3
63	2	3.3
64	2	3.3
65	1	1.7
66	5	8.3
67	3	5.0
68	2	3.3
70	3	5.0
75	1	1.7
77	1	1.7

Internal rotation of the hip with the hip flexed - left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
15	3	5.0
19	2	3.3
20	1	1.7
21	2	3.3
22	1	1.7
23	1	1.7
24	1	1.7
26	3	5.0
28	1	1.7
29	1	1.7
31	3	5.0
32	1	1.7
33	3	5.0
34	2	3.3
36	5	8.3
37	3	5.0
40	2	3.3
42	4	6.7
43	3	5.0
45	2	3.3
46	5	8.3
47	2	3.3
49	1	1.7
50	1	1.7
51	1	1.7
54	2	3.3
55	1	1.7
56	2	3.3
63	1	1.7

Internal rotation of the hip with the hip flexed - right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
6	1	1.7
15	1	1.7
16	1	1.7
20	1	1.7
21	3	5.0
22	3	5.0
23	1	1.7
25	1	1.7
26	2	3.3
27	3	5.0
29	1	1.7
30	1	1.7
31	4	6.7
32	2	3.3
33	3	5.0
34	1	1.7
36	2	3.3
37	3	5.0
38	4	6.7
41	4	6.7
42	1	1.7
45	1	1.7
46	2	3.3
47	1	1.7
48	1	1.7
49	2	3.3
50	2	3.3
51	2	3.3
52	1	1.7
53	1	1.7
54	1	1.7
55	1	1.7
57	1	1.7
59	1	1.7

Calcaneal Stance - inverted--left foot, N=8

Raw Score (degrees)	RS Distribution Count	Percent
1	4	50.0
2	3	37.5
4	1	12.5

Calcaneal Stance - inverted--right foot, N=29

Raw Score (degrees)	RS Distribution Count	Percent
1	16	55.2
2	7	24.1
3	2	6.9
4	3	10.3
6	1	3.4

Calcaneal Stance - everted--left foot, N=44

Raw Score (degrees)	RS Distribution Count	Percent
1	6	13.6
2	17	38.6
3	5	11.4
4	6	13.6
5	4	9.1
6	3	6.8
7	1	2.3
9	2	4.5

Calcaneal Stance - everted--right foot, N=21

Raw Score (degrees)	RS Distribution Count	Percent
1	3	14.3
2	5	23.8
3	6	28.6
4	4	19.0
5	1	4.8
6	1	4.8
9	1	4.8

Tibial Stance - varus--left leg, N=58

Raw Score (degrees)	RS Distribution Count	Percent
1	3	5.2
2	4	6.9
3	3	5.2
4	9	15.5
5	7	12.1
6	13	22.4
7	4	6.9
8	3	5.2
9	5	8.6
10	4	6.9
11	1	1.7
12	1	1.7
14	1	1.7

Tibial Stance - varus--right leg, N=59

Raw Score (degrees)	RS Distribution Count	Percent
1	2	3.4
2	3	5.1
3	9	15.3
4	4	6.8
5	11	18.6
6	9	15.3
7	4	6.8
8	4	6.8
9	6	10.2
10	1	1.7
11	2	3.4
12	2	3.4
16	1	1.7
20	1	1.7

Tibial Stance - valgus--left leg, N=1

Raw Score (degrees)	RS Distribution Count	Percent
3	1	100.0

Corrected Calcaneal Stance - inverted--left foot, N=13

Raw Score (degrees)	RS Distribution Count	Percent
1	11	84.6
2	1	7.7
5	1	7.7

Corrected Calcaneal Stance - inverted--right foot, N=28

Raw Score (degrees)	RS Distribution Count	Percent
1	11	39.3
2	5	17.9
3	1	3.6
4	3	10.7
5	5	17.9
6	1	3.6
7	1	3.6
8	1	3.6

Corrected Calcaneal Stance - everted--left foot, N=22

Raw Score (degrees)	RS Distribution Count	Percent
1	10	45.5
2	7	31.8
3	2	9.1
4	1	4.5
5	2	9.1

Corrected Calcaneal Stance - everted--right foot, N=10

Raw Score (degrees)	RS Distribution Count	Percent
1	4	40.0
2	2	20.0
3	3	30.0
4	1	10.0

Corrected Tibial Stance - varum--left foot, N=52

Raw Score (degrees)	RS Distribution Count	Percent
1	10	19.2
2	3	5.8
3	7	13.5
4	11	21.2
5	8	15.4
6	2	3.8
7	4	7.7
8	2	3.8
9	4	7.7
12	1	1.9

Corrected Tibial Stance - varum--right foot, N=50

Raw Score (degrees)	RS Distribution Count	Percent
1	5	10.0
2	6	12.0
3	3	6.0
4	7	14.0
5	13	26.0
6	4	8.0
7	3	6.0
8	1	2.0
9	3	6.0
10	2	4.0
12	1	2.0
14	2	4.0

Corrected Tibial Stance - valgum--left foot, N=2

Raw Score (degrees)	RS Distribution Count	Percent
4	1	50.0
5	1	50.0

Corrected Tibial Stance - valgum--right foot, N=2

Raw Score (degrees)	RS Distribution Count	Percent
4	2	100.0

Internal rotation of the lower leg--left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
9	2	3.3
13	1	1.7
15	2	3.3
17	1	1.7
18	1	1.7
20	1	1.7
21	1	1.7
22	1	1.7
23	1	1.7
24	3	5.0
25	1	1.7
26	1	1.7
27	1	1.7
28	1	1.7
29	1	1.7
30	1	1.7
31	1	1.7
32	1	1.7
34	3	5.0
35	2	3.3
36	2	3.3
37	1	1.7
38	1	1.7
39	4	6.7
40	4	6.7
41	4	6.7
42	1	1.7
43	1	1.7
44	2	3.3
45	2	3.3
46	3	5.0
48	1	1.7
49	1	1.7
50	3	5.0
51	1	1.7
53	1	1.7

Internal rotation of the lower leg--right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
5	1	1.7
9	2	3.3
10	1	1.7
11	2	3.3
12	1	1.7
13	1	1.7
15	4	6.7
16	3	5.0
17	1	1.7
19	3	5.0
20	3	5.0
21	1	1.7
22	2	3.3
25	5	8.3
26	1	1.7
28	4	6.7
29	1	1.7
30	2	3.3
31	2	3.3
32	2	3.3
33	1	1.7
34	3	5.0
36	1	1.7
38	3	5.0
40	2	3.3
41	1	1.7
44	1	1.7
45	3	5.0
46	1	1.7
48	1	1.7
52	1	1.7

External rotation of the lower leg--left leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
10	1	1.7
11	2	3.3
14	1	1.7
20	1	1.7
21	4	6.7
22	1	1.7
23	2	3.3
25	1	1.7
27	2	3.3
30	2	3.3
31	4	6.7
34	1	1.7
35	1	1.7
36	5	8.3
37	1	1.7
38	2	3.3
39	3	5.0
40	2	3.3
41	3	5.0
42	2	3.3
43	3	5.0
44	1	1.7
45	2	3.3
46	1	1.7
47	1	1.7
48	1	1.7
50	3	5.0
51	3	5.0
56	2	3.3
58	1	1.7
59	1	1.7

External rotation of the lower leg--right leg, N=60

Raw Score (degrees)	RS Distribution Count	Percent
11	1	1.7
17	1	1.7
18	1	1.7
22	1	1.7
25	1	1.7
26	1	1.7
27	1	1.7
29	1	1.7
31	2	3.3
32	1	1.7
36	1	1.7
37	1	1.7
39	2	3.3
40	1	1.7
41	3	5.0
42	4	6.7
44	2	3.3
45	1	1.7
46	3	5.0
47	2	3.3
48	1	1.7
49	1	1.7
50	2	3.3
51	2	3.3
52	2	3.3
54	3	5.0
55	2	3.3
56	4	6.7
57	2	3.3
58	2	3.3
59	1	1.7
62	1	1.7
63	2	3.3
64	3	5.0
74	1	1.7

APPENDIX G

Name_____ _____ Height_____

Address_____ Weight_____

Phone_____ Sex_____ Age_____

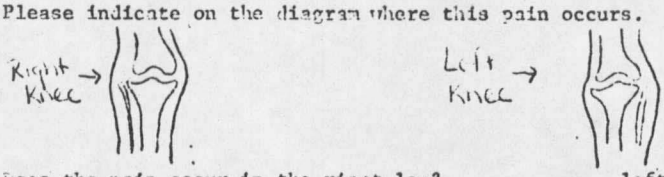
1. How often do you run each week? Number of days_____

   Miles/day_____ Type of surface_____ Shoe Brand_____

How long have you been running seriously?_____

2. Have you ever experienced knee pain?_____

3. Please indicate on the diagram where this pain occurs.



4. Does the pain occur in the right leg?_____left leg?_____

5. The knee pain occurs: right knee- often seldom constantly

   left knee- often seldom constantly (Circle one)

6. The knee pain is: right knee - past present reoccurring

   left knee - past present reoccurring (Circle one)

7. Please list activities other than running in which you participate that aggravate the knee pain.

8. Have you ever had surgery on your knee? right_____ left_____

9. Have you ever experienced: Achilles tendonitis_____

   Shin Splints_____ Low Back Pain_____

   Morton's Syndrome_____

10. Where you ever a member of an athletic team? Yes_____ No_____

    What team?_____ When?_____

********* I would like a copy of the results of this study.

Yes_____ No_____

APPENDIX F

MEAN SCORES, STANDARD DEVIATIONS AND UPPER AND LOWER LIMITS OF SCORES FOR EACH OF THE 22 MEASUREMENTS

Measurement	Mean (in degrees)	S.D. (in degrees)	Upper and Lower Limits of Scores (in degrees)
Eversion-left foot	4.8475	2.7843	1-14
Eversion-right foot	4.0833	3.0659	1-15
Inversion-left foot	11.45	5.1959	3-24
Inversion-right foot	13.3833	4.7802	3-22
Forefoot varus-left foot	4.3529	2.7511	1-9
Forefoot varus-right foot	3.4545	2.2513	1-8
Forefoot valgus-left foot	3.4231	1.9631	1-9
Forefoot valgus-right foot	4.7407	2.5053	1-9
Dorsiflexion-left foot knee extended	16.6667	6.7364	2-32
Dorsiflexion-right foot knee extended	18.1667	6.5307	3-33
Dorsiflexion-left foot knee flexed	17.7667	8.0008	4-36
Dorsiflexion-right foot knee flexed	17.4	7.4315	4-36
Hamstrings-left leg	22.2167	12.1990	1-52
Hamstrings-right leg	21.4333	11.7997	2-50

Measurement	Mean (in degrees)	S.D. (in degrees)	Upper and Lower Limits of Scores (in degrees)
External rotation at the hip-hip extended-left leg	57.6167	10.8442	34-83
External rotation at the hip-hip extended-right leg	63.6167	12.1308	15-92
Internal rotation at the hip-hip extended-left leg	35.7	11.5323	11-64
Internal rotation at the hip-hip extended-right leg	36.4833	10.1489	18-66
Internal rotation at the hip-hip flexed-right leg	35.8167	11.8429	6-58
Internal rotation at the hip-hip flexed-left leg	36.85	11.6224	15-63
External rotation at the hip-hip flexed-right leg	56.8167	10.0650	25-77
External rotation at the hip-hip flexed-left leg	50.9333	9.3824	30-67
Calcaneal Stance-inverted-right foot	1.8621	1.2740	1-6
Calcaneal Stance-inverted-left foot	1.75	1.0351	1-4
Calcaneal Stance-everted-left foot	3.2273	2.0216	1-9
Calcaneal Stance-everted-right foot	3.1905	1.8606	1-9

Measurement	Mean (in degrees)	S.D. (in degrees)	Upper and Lower Limits of Scores (in degrees)
Tibial Stance-varum-left foot	5.9138	2.8364	1-14
Tibial Stance-varum-right foot	6.2034	3.5026	1-20
Tibial Stance-valgum-left foot	3.00	.000	3
Tibial Stance-valgum-right foot	0.00	.000	0
Corrected Calcaneal Stance-inverted-left foot	1.3846	1.1209	1-5
Corrected Calcaneal Stance-inverted-right foot	2.9286	2.1244	1-8
Corrected Calcaneal Stance-everted-left foot	2.000	1.2724	1-5
Corrected Calcaneal Stance-everted-right foot	2.100	1.1005	1-4
Corrected Tibial Stance-varum-left leg	4.3269	2.6251	1-12
Corrected Tibial Stance-varum-right leg	5.1800	3.1473	1-14
Corrected Tibial Stance-valgum-left leg	4.500	.7071	4-5
Corrected Tibial Stance-valgum-right leg	4.000	.000	4
Internal leg rotation-left leg	34.80	11.577	9-53
Internal leg rotation-right leg	26.600	11.4879	5-52

Measurement	Mean (in degrees)	S.D. (in degrees)	Upper and Lower Limits of Scores (in degrees)
External leg rotation-left leg	36.3833	12.0593	10-59
External leg rotation-right leg	45.9667	13.1729	11-74

[redacted]

Flood, Janice E
Selected lower extremity alignment and range of motionmeasurements ...

DATE	ISSUED TO
MAY	105 W. Cent. SS 586-4146 Don Hamington
DEC 8 1982	730 Highland Ct Kelley Beasley 587-8274
	Langford 1 Matt Ball 994-26

[redacted]